PORTLAND ENERGY CONSERVATION, INC.

With

Partner Y

Final Commissioning Report

Prepared for:

Building X

PECI
1400 SW 5th Ave
Suite 700
Portland, OR
97201

TELEPHONE:
(503) 239-9232
FAX:
(503) 295-0820

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Executive Summary

The client requested that Portland Energy Conservation, Inc. (PECI) provide direction and oversight for the commissioning of Building X. PECI engaged Partner Y to work as part of the commissioning team and provide primary support for the construction phase commissioning. The project incorporated a highly energy efficient design with the goal of obtaining a high performance, low maintenance, low operating cost facility achieved through sustainable and energy efficient design features. The project had two primary commissioning-related goals: 1) to incorporate commissioning to ensure that the facility would operate to meet the energy efficient goals and design, and 2) to serve as a learning experience for the client. This is the first time the client has required commissioning starting in the design phase and continuing through the construction and acceptance phase of a project. Through the lessons learned, the client has gained a better understanding of how to more successfully incorporate commissioning into a construction project.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) defines building commissioning as "the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent." The owner of a facility can further define goals for commissioning according to their desired outcomes for the selected facility.

Building X is a 20,000 square foot facility that houses administrative and morgue space for the client's examiners. The total construction cost of this facility was approximately $xx million. The project began construction on date xx. The project was occupied by the users on/or around date xx. The commissioning process was fully incorporated from design through construction and acceptance of the project.

Design phase commissioning included an extensive design document review process which is typical for design phase commissioning. A total of 42 items needing additional clarification and correction were identified. Fourteen of these items were critical to the successful completion of the project and ongoing operation and maintenance of the facility. These items are listed and described in the body of the report. The purpose of review during design not only helps to better define the requirements of the mechanical and electrical systems, but ultimately reduces the first cost of the project by giving the contractors clear definition of the requirements of the systems during the competitive bidding portion of the project. All items from these review(s) were tracked and reviewed with the design team during design, with most comments and issues being resolved.

Construction phase commissioning included an extensive review of the mechanical and electrical submittals. This is a typical construction phase commissioning task. There were a total of 87 comments made during the reviews. Several were critical to obtaining a successful project. These are listed and described in the body of the report. Thirteen job site observations were performed during construction that resulted in a list of 50 issues. Site observations are beneficial because they identify problems early in the process where they can be ameliorated more cost effectively. The primary purpose of the site observations along with prefunctional testing is to prepare the equipment and systems for functional performance testing. Functional performance testing ensures that the systems are fully integrated and perform optimally and according to design. Functional performance testing is the heart of the commissioning process.

Commissioning included functional performance testing for the HVAC-R systems and the electrical systems including daylighting / dimming controls and emergency power equipment, room isolation / pressurization control, the domestic hot water system and the building automation system. Some systems had up to 30 tests performed to insure proper operation. There were a total of 25 issues identified during the functional testing procedures. Most of the issues were easily resolve. The three major problem areas of concern were the air pressure differential between the Administrative and Morgue Area, humidification, and supply air stratification in office spaces due to high ceilings. These problems are mainly design issues and are described in detail in the body of the report.

Commissioning also included reviewing the operation and maintenance manuals and insuring that training agendas were developed and followed. A total of 35 comments were offered on the O&M manuals that improved their content. The owner / user was trained on twenty-one (21) systems on the project. All training sessions appeared to be very informative to the users and staff. The users commented that they were very glad that the commissioning agent reviewed and attended training to help spur dialogue regarding the operation of the equipment.

Seven major commissioning recommendations were generated as a result of this project for future commissioning projects. The following summarizes the list that is described in more detail in the report:

1. Commissioning should be clearly addressed in the contract documents. This includes construction and acceptance phases of commissioning. When contractors understand the commissioning process and it is clearly specified, they see how it benefits them and are willing partners in the process. In future projects, the client should consider bidding the commissioning of the MEP systems as an alternate. This will allow an accurate and competitive bid value to be assigned to this task.

2. Include commissioning during project conception. It is quite possible that the problems that occurred regarding the lack of a rigorous commissioning specification would not have occurred if commissioning had been included during the initial budget development for the project. The project budget needs to consider commissioning for all stages of the project from design through acceptance. Including commissioning during project conception and budgeting facilitates communication and the understanding by all team members that commissioning is important to the client.

3. Value Engineering should be performed on the project by the commissioning team prior to bidding the project. This way, questionable items can be bid as alternates and competitive bid pricing can be seen for these items in lieu of waiting until a contractor is already on board and negotiating a price with one contractor. The contractor has no incentive to offer a low price for items once the project is awarded to them.

4. The owner should make it clear to the design team and contractors that the commissioning provider is part of the project team and is therefore in the loop to receive any communications related to the project. Because the commissioning team was not copied on most correspondence on this project it was very difficult to understand what change orders and modifications were approved and should be

built. An informed commissioning provider can, for example, question the contractor regarding required rough-ins prior to the installation of drywall and often save the contractor time and money.

5. The contract should specify that the O&M manuals be provided within 30 - 60 days of approved submittals. This would allow the commissioning agent to have access to the needed documentation early in the process, allowing for a more timely delivery of the prefunctional and functional performance tests.

6. The completion of the commissioning prefunctional and functional testing should be tied to substantial completion of the project. Once substantial completion is granted on a project, the owner looses a great deal of leverage with the contractor. On this project, the contractor was much more responsive to commissioning related items until substantial completion was granted.

7. In the future the client should consider providing training or educational seminars, and materials for the tenants or building occupants regarding the benefits and use of a buildings energy-saving and sustainable features prior to occupancy. It appears that the tenant for this facility, because they lacked an understanding the benefits of the daylighting feature and how to interface with it, chose to override it by installing floor-to-ceiling blinds.

In some cases commissioning for this facility went beyond its usual scope (*identifying* issues) by attempting to offer solutions for the problems and working to implement those solutions. The commissioning provider also took over the contractor's job of developing the prefunctional tests when the contractor failed to deliver them according to the specification. Because commissioning was not clearly stated in the specification, a great deal of time was spent by the commissioning team providing documentation to convince the contractor that a certain level of commissioning was included in the project and that the contractor was responsible for several commissioning tasks.

As with most projects, Building X was not without problems. There were many challenges that were addressed by the design, construction and commissioning teams. While not perfect, the facility is functioning more efficiently and has had fewer problems due to the commissioning effort. Many of the items noted during the commissioning process would have been overlooked or ignored by the contractor and design team if these issues had not been brought to the forefront in a timely manner. The commissioning process helped the owner become more aware of the issues on the project and their potential for problems during the life of the building if they were not addressed. The client should be commended for their untiring effort regarding energy conservation and building sustainability, of which commissioning proves to be a vital tool for ensuring that client-owned buildings are operating according to design and the owner's requirements.

Project Overview

Building X is a 20,000 square foot facility that houses administrative and morgue space for the client. The administrative portion of the facility consists of ten (10) private offices, four (4) large open office areas, conference space for approximately thirty (30) people and support areas. The morgue portion of the facility has a large open autopsy area with accommodations for four (4) workstations, two (2) special autopsy rooms, two (2) body coolers and a body receiving area. The administration and morgue areas are separated by two Bio-vestibules designed to eliminate air movement from the morgue to the administration areas.

The total construction cost of this facility was approximately $xxM. The project began construction on date xx. The project was occupied by the users on/or around date xx.

The following firms were involved in this project:

Team Member	Firm	Contact
Xxx	xxx	xx

There were also several key people with the client that were instrumental in the success of this project. Some of these include: xx.

The commissioning for this project was a joint venture between PECI located in Portland, OR and Partner Y located in city xx. The commissioning portion of this project was divided into four (4) phases. These were Design Review Phase, Construction Phase, Acceptance Phase and Warranty Phase. Activities for these phases are outlined as follows.

Design Review Phase

Design Document Review

To begin the design phase commissioning, PECI developed a design phase commissioning plan to help guide the process. Appendix C contains the plan titled *Commissioning Plan – Design Phase*.

One of the first tasks performed by the commissioning team was to review the design documents (plans and specifications). These documents were reviewed twice during design. The first review identified a total of forty-two (42) items needing additional clarification and/or correction. Fourteen (14) of these comments were noted as being critical to the successful completion of the project. Some examples of the critical comments were as follows:

- Startup execution and training language not included in the specification for each piece of equipment
- Pressure relationships for different areas should be defined on the drawings.
- A minimum differential across all doors should be a minimum of 0.01" water column.
- Service clearances not adequate around equipment.
- Chiller and Fire Alarm sequence not clearly defined.
- Boiler piping schematics not reflective of the designer's intent.
- Sequence of operation of AH-1, AH-2, AH-3 and Humidifier not clearly defined.

Appendix A contains the full list of issues identified during the construction document review, titled *Commissioning Review of Construction Documents.*

The second review was made after the contract was awarded to XX Construction Company (approximately 20% into the construction of the project). This review reiterated several of the concerns mentioned during the first review of the contract documents. There were a total of fifteen (15) comments mentioned during this review. These comments also included several value-engineering items that could have resulted in cost savings for the project. The value engineering comments were discussed with the design team and it was determined that they would not be included in the project. One of the reasons that the designers did not incorporate some of these items was that they felt that the contractor would only give back pennies on the dollar. The contractor had already obtained the project through the competitive bidding process and did not have any incentive to offer realistic compensation for the suggested value engineering items. We will speak to this item later in this report under "Future Commissioning Recommendations".

These reviews not only helped to better define the requirements of the mechanical and electrical systems, but ultimately reduced the first cost of the project by giving the contractors clear definition of the requirements of the systems during the competitive bidding portion of the project. All items from these reviews were tracked and reviewed with the design team during design, with most comments being resolved.

The cleint was very apprehensive about how to include commissioning in the specifications because when the project was first appropriated, it was unclear if funding would be adequate to include commissioning beyond the design phase. Therefore the specification contained language that was somewhat vague regarding how commissioning would be performed during construction. However, it did include enough language to require a fairly typical level of commissioning by the contractor. Problems arose because the word "commissioning" didn't appear in the specification. This caused the contractor to feel that they had been blind-sided and subsequently they wanted to use the change-order process on any of their "commissioning" related tasks. We will speak to this item later in this report under "Future Commissioning Recommendations".

Construction Phase

Commissioning Review of Mechanical and Electrical Submittals

The submittals for major mechanical and electrical equipment were reviewed by the PECI commissioning team. There were a total of eighty-seven (87) comments made during these reviews. These comments addressed a broad array of issues. Samplings of these issues are as follows:

- Wrong voltage noted on mechanical equipment.
- The maximum evaporator water pressure drop exceeded by the chiller manufacturer.
- Motor horsepower increased on mechanical equipment
- Incorrect number of lamps shown in some of the lighting fixtures.
- The outside air delivered to the building through a terminal unit will not function properly. This item dated back to a construction document review comment. The designer rejected this comment.
- Wrong number of sections shown for main distribution panel.
- Wrong type of lighting fixture (type "E") noted to be provided by contractor.
- Lighting fixtures submitted with the wrong total harmonic distortion percentage (%THD) provided.
- Not enough information on Refrigerated Rooms, supports and anchors to properly evaluate the system.
- Piping sizing on the humidifier was noted as being questionable. This item was rejected by manufacturer. Later in the project, problems arose on this system and the manufacturers recommended increasing the pipe sizing.

Appendix B contains the commissioning documentation for the submittal review titled *Commissioning Review of Mechanical and Electrical Equipment Submittals*

The designers, contractors and manufacturers adequately addressed most of the items noted during the review of the submittals, with the exception of comments regarding the humidifier and building pressurization. To date, problems with humidification and building pressurization issues remain open.

Commissioning Plan – Construction Phase

Because commissioning is still a relatively new design / construction process in the Southeastern United States, the commissioning team felt that it was very important to develop a precise plan that would guide the team through the entire process. With this in mind, the "Commissioning Plan – Construction Phase" document was developed. This plan outlined very specific requirements for each member of the design and construction team. Some of the broad areas outlined in this plan were as follows:

- Provided direction for the development of commissioning activities during the latter part of the design phase.
- Provided direction for the commissioning process during the construction phase of the project.
- Provided additional direction and support to items not fully detailed during the design phase of the project.
- Provided scheduling of all commissioning activities.
- Developed lines of reporting regarding approvals and coordination for the project.
- Outlined equipment to be commissioned.
- Provided contacts, numbers and addresses for each member of the design and construction team.
- Outlined execution of Prefunctional checklists for equipment startups.
- Listed requirements for O&M manual reviews.
- Listed requirements for training of the owner personnel.
- Provided flow diagrams outlining Prefunctional and Functional testing requirements.
- Listed commissioning related requirements for each team member for this project.

Appendix D contains the *Commissioning Plan – Construction Phase* for this project. This document was found to be a very valuable tool during the construction process. There were several times when the contractor questioned their contractual responsibilities regarding different functions of the commissioning process. Each time, the *Commissioning Plan – Construction Phase* document was utilized to resolve these issues.

Construction Phase Commissioning Scoping / Kick-Off Meeting

This meeting was held on February 6, 2001. The purpose of the meeting was to review the Construction Phase Commissioning Plan with the contractors. We presented the commissioning plan which outlined each design and construction team member's responsibilities regarding commissioning on the project. The general contractor was very reluctant to agree with any of the items reviewed during this meeting. They said that they asked during the bidding process whether the project was to be commissioned and were not given a clear response. We assured the contractor that commissioning on this project would be limited to the items outlined in the specifications. The contractor stated that commissioning was not required per the specifications. With this in mind, the contractor was told that commissioning was in the specifications and a spreadsheet would be made that outlined each item to be commissioned, along with the specification that required the commissioning. This spreadsheet was made and presented to the construction team

during the next regular monthly meeting. After a great deal of discussion, the contractors seemed to become more receptive to the idea of commissioning on the project. Appendix G contains the meeting minutes from the Commissioning Scoping Meeting.

Job Site Observations

There were a total of thirteen (13) formal job site observations made by the commissioning team. During these site visits, construction issues that could affect the systems that would be commissioned were reviewed and comments were given to the design / construction team. Some examples of items noted during job site observations are as follows:

- Contractor was advised to maintain adequate distance from walls to allow duct insulation.
- All ductwork and valves installed prior to the roof being poured were noted to be covered to prevent damage / contamination.
- Lightweight concrete was poured before all MEP items were sealed. The commissioning team evaluated damage and made recommendations regarding cleaning to the CM.
- Advised the contractor regarding proper air filter installation before starting of unit.
- Observed most prefunctional tests. Most equipment required re-tests before all items on test were approved.
- Identified sump pump in “Backflow Preventer Vault” that did not have an electrical connection.
- Identified isolation valves missing on plumbing fixtures.
- Advised the construction team that proper clearance was not being maintained around equipment.
- Contractor was advised that adjustable circuit breaker setting should be provided for all breakers in main distribution panel.
- Proper clearance was not being maintained in front of electrical equipment – code violation.
- Fire / Smoke walls were not being sealed properly – code violation.
- Normal and Emergency circuits in the same junction box – code violation.
- Power was not provided for data racks.
- Carbon Monoxide System was not roughed-in for the Body Receiving Area.
- Voltage meter on main distribution panel was not calibrated.
- Redundant electrical feeds to coolers were not provided.
- Body cooler should be tied to building management system.
- Excessive condensation on insulation in mechanical room.

As can be seen from the brief description of items mentioned above, it was very beneficial to have the commissioning agent perform periodic site observations. Many of the items

listed above and shown in the "Job Observation Report" tab of this report would not have been caught if these job observations had not been performed.

Appendix H contains the full list of issues identified during the construction site visits.

Acceptance Phase

Prefunctional Checklists

In the acceptance phase of the project, the commissioning agent and construction team went through each piece of equipment that was slated to be commissioned. The first portion of this phase required, according to the specification, that the contractor complete the "Pre-functional Checklists". The purpose of the checklists is to insure that all of the components of a system are installed and operating properly in preparation for functional performance testing. These checklists were written as a joint venture between the commissioning agent and construction team. This task was performed as follows:

- The contractor provided "can" checklists from the manufacturer of each piece of equipment commissioned.
- The commissioning agent wrote the "Prefunctional Checklist for the project from this information, along with other items needed to make the checklists complete.
- The construction team was allowed to comment and make suggestions to alter the checklists if they did not agree with them or felt that they would be more applicable performed in a different way.
- The contractor filled out the checklists and returned them to the commissioning agent.
- The checklists were reviewed to make sure all items were covered.

The contractor was not very timely in providing most of the "can" checklist information, even though this information was required by the specification and was readily available from the equipment manufacturer. Once it became obvious that the contractor was not willing and/or able to collect the "can" checklists from the manufacturers, the commissioning agent stepped in and performed this task. The commissioning agent went to the contractor's office and went through all submittals on the equipment that was being commissioned. The needed information for the Prefunctional Checklists was copied. Some of the information was obtained from vendor catalogs and websites on the internet. Because the contractor failed to perform this specified task, the writing of the Prefunctional Checklists was delayed by several months.

The process for the Prefunctional Checklist testing was very straightforward. However, it became clear very early that, because commissioning was not a standard process, the commissioning agent would have to become more active in the process or the contractor's commissioning responsibilities would not get done correctly and on time. With this in mind, PARTNER Y worked "hand-in-hand" with the mechanical and electrical contractor on most of the prefunctional checklist to insure that the appropriate information was collected and documented. Because the contractor would not review the Prefunctional Checklist in the field prior to the site observation by the commissioning agent, most of the equipment required two or more reviews before the equipment performed properly and

had adequate documentation. All prefunctional tests can be found in Appendix I – *Prefunctional Tests*.

Some of the items that were noted during the prefunctional tests were as follows:

- Belts were loose on AHU.
- Control wiring was loose and would be damaged during maintenance.
- Grounding conductors were not properly connected at tri-pod type ground.
- Equipment not labeled
- Smoke Detectors installed in wrong location.
- Smoke detectors installed within 3'-0" of supply diffusers.
- Grounding conductors not connected at building automation system.
- Meter not calibrated on main distribution panel.
- Strainers on pumps were very dirty.
- Circuit for heat-tape on chilled water piping not turned on.

Functional Performance Testing

Once all components of the systems were found to be working properly, we proceeded to the functional performance testing of each system. Functional performance testing is the process of testing the system as a whole to insure that it is operating at maximum efficiency and according to the design intent. Each system had between 15 and 30 tests performed to insure that it was operating properly. Some examples of the major tests performed on the air-handling units are as follows:

- Units "OFF" / "ON" by BAS (Building Automation System) under proper conditions
- Temperature Control – Economizer
- Duct Static Pressure Control
- High Static Pressure Alarm and Shutdown
- Discharge Temperature Reset
- Smoke / Fire Condition Shutdown
- Building Static Pressure
- AHU Filter Drop
- Proper water and air flows
- Proper pressure differential between Administrative and Morgue areas.

Some of the items that were noted during the functional tests were as follows:

- Outside air damper was not functioning properly.
- Flow and tamper switch at PIV were not working.
- Remote fire alarm monitoring station was not being notified.

- Pump did not have proper impeller installed.
- Terminal unit in morgue did not have proper air flow.
- Condensate on piping insulation.
- Bypass function was not working properly on UPS system
- Lighting sensors were adjusted for proper operation.

Most of the systems tested preformed according to design parameters and required very few adaptations in order to have them operate properly. The three major problem areas of concern were the air pressure differential between the Administrative and Morgue Areas, the humidifier, and supply air stratification in office spaces due to high ceilings.

Air Pressure Differential

Of the three items mentioned, the air pressure differential was of the most concern to the commissioning team. This concern relates to the potential for health hazards due to contaminated air entering the administration area from the morgue. The commissioning team questioned this item on several occasions, starting as early as the design review and then again during the construction and acceptance stages of this project. On each occasion, the designers stated that they were not concerned with the design and rejected the commissioning team's concerns. It wasn't until the functional testing of the air-handling units that the commissioning team was able to demonstrate that there was a problem, and an alternative solution was designed. The design solution took several months to implement. The commissioning team worked very closely with the designers and contractors to adjust the existing system to obtain proper pressure readings until the new solution could be installed. This allowed the users to occupy the space in July while the permanent solution was not installed until October.

The commissioning agent made several recommendations to the mechanical designers for possible solutions to resolve the air pressure differential problem when this problem was documented in mid-July. The design team took several weeks to respond to this issue. The design team's final response was one of the solutions that was recommended by the commissioning agent several weeks before, with one exception. The commissioning agent recommended that the amount of outside air be increased because the present design was marginal and did not have enough safety built in to cover the complete dynamics of the building. Unfortunately, the designers did not heed this recommendation and proceeded without increasing the outside air in the system. During functional testing of the air-handling units in early February, pressure readings were taken at the bio-vestibule doors that separate the Administration and Morgue areas and very marginal pressure differential readings were obtained.

Typically a pressure differential of a minimum of 0.01 in. w.g. pressure should be maintained between areas to achieve proper airflows. Some examples of these readings are as follows:

BIO VESTIBULE - 153

Door 156A – Air moved from office to Bio Vestibule (0.006 in. w.g.)

Door 153 – Air moved from morgue to Bio Vestibule (0.006 in. w.g.)

Door 154 – Air moved from Bio Vestibule to Storage 154 (0.0014 in. w.g.)

Door 155 – Air moved from Bio Vestibule to Storage 155 (0.003 in. w.g.)

These pressure differential readings were so marginal that additional tests were developed by the commissioning agent to see how the system would react during different dynamic conditions. One of the tests performed was to "open" the door between the Morgue and the Bio-vestibule and measure the effect this had on the pressure differential. The following results were noted:

BIO VESTIBULE - 153

At door 156A – Air moved from office to Bio Vestibule (0.006 in. w.g.) - Door from Morgue to Bio Vestibule (153) was closed.

Door from Morgue to Bio Vestibule (153) was opened. The new reading at door 156A was (-0.001 in. w.g.) which means that air was moving from the Bio Vestibule into the office. This air movement did not meet the owners design parameter and could cause a hazardous condition.

As shown above, the measurements taken during functional tests reflected improper air movement between the Administration and Morgue areas under certain dynamic conditions. After further adjustments of the outside air control during April and May of 2002 by the design team, the HVAC system appears to maintain the pressure differential. Although this issue is considered resolved, the commissioning provider still feels the pressure differential could be more rigorous. There is still very little room for error. If the controls move slightly out of calibration or any adjacent spaces have a change in pressure such as could occur if the delivery doors are opened during an autopsy, a resulting pressure change could easily cause odors to flow from the morgue into the lobby. However, as long as the pressures in the adjacent spaces remain static, the pressure differential provided between the autopsy room and the adjacent spaces should contain the ordors.

Please refer to our site review of the system dated 02/25/02 in Appendix F – *Correspondence*.

Humidifier

The humidifier (H#1) has been a source of constant problem to the users. This system was not functionally tested because it has not been operable for any length of time. During the final functional testing, this unit was reset and it tripped out due to electrical overloads. The alarm history for this unit was checked and it was found to have tripped several times. The contractor and user have been questioned about this item. The user advised Partner Y that the humidity level in the morgue area has been very low all heating season. The humidity reading during the day of the final functional testing was 9%, compared to the design range of 30% to 60%. The contractor was questioned about this item and they stated that the manufacturer had been advised of this recurring issue. The manufacturer recommended increasing the steam pipe from the humidifier to the air handling units from a 1 ½" to a 3" pipe. This modification was made sometime before our final functional testing in early February but did not appear to correct the problem. A portion of the supply air temperature sequence of controls is tied to the room relative humidity. Since the humidifier was not operational, Partner Y was unable to verify that portion of the control sequence. It is recommended that the design team assist in the resolution of this issue.

Temperature Stratification

Another item identified during the final functional testing in early February was cold temperature in the perimeter offices. The users also complained about the temperature in these rooms as well as the length of time it takes for these rooms to reach reasonable temperatures in the morning. Temperature readings were taken at several different locations within the offices with a difference from the floor to ceiling being approximately eight degrees. Due to the high ceilings (approximately 10'-0") in the office area, stratification appears to be occurring. The air is also returned at the ceiling, reducing the possibility of warm air reaching the occupants of the room. One option suggested to the designer was to consider a different type of ceiling diffuser that provides more discharge

velocity, directing warm air closer to the floor. Any compromises with alternate ceiling diffuser selections should be discussed prior to any changes. Another possible solution would be to increase the (heating) air volume CFM delivered to the space. As an example, the present design for most of the perimeter offices require approximately 50% decrease in air volume during the heating cycle. The designers should review these items and provide direction.

During April and May of 2002, the design team visited the site and made additional adjustments to the supply air diffusers in the perimeter offices. These adjustments directed the air toward the floor. It is difficult to say if this will solve this issue, or not since the system is in the cooling mode at that time. One potential problem that this could cause is "draft" within the offices. The designer / users should continue to follow this item during the heating season of 2003.

Appendix F contains documentation of all commissioning issues identified during construction commissioning and the resolution status. All functional tests can be found in Appendix J – *Functional Tests*.

Recommended Changes for this Project

The following are recommendations for this and future projects:

1. The designers should actively pursue a more rigorous solution for the air pressure differential problem between the Administration and Morgue areas. This would allow for a greater air pressure differential between the Administration and Morgue areas and greatly reduce the potential of contaminated air from migrating into the Administration area. The designers will need to review this item closely to insure that the present coil selection and other items are sized properly for the selected solution.

2. A major design requirement of this project was to maintain proper air pressure differential between the administration and morgue areas. This item has been addressed at length earlier in this report. There are presently pressure differential monitors in the administration and morgue areas. These monitors test the pressure difference between these areas. The system is presently designed to alarm only if AH#3 (exhaust system for the morgue area) fails to operate. It is recommended that the control sequence be modified to provide an audible tone to annunciate when the morgue becomes positive to the administration area (air moves from morgue into office). There would be no additional hardware required for this modification. Additional programming would be required to allow the control system to operate as described above.

3. The designers should actively pursue a solution for the humidifier problem. The contractor appears to have exhausted all recommendations made by the manufacturer and nothing has resolved the problem. It is suggested that the designer and manufacturer meet at the site to discuss this item and bring it to some form of resolution.

4. The designers should review the options for addressing the cold perimeter offices and provide direction.

Lighting Issues:

Daylighting

The client selected to initiate daylight harvesting as an innovated energy feature for the building. This included special glazing applications and the installation of light shelves to enhance the measure. The daylighting controls were commissioned and adjusted during construction and were found to be functioning as expected. However, as a result of the installation of floor-to-ceiling blinds by the tenant, the design intent for the daylight-harvesting feature is not met. Unfortunately the change order from the client to replace the floor-to-ceiling blinds with the appropriate glare-reducing half blinds was rejected. Why this happened is not completely clear but it may have been too expensive to remove the installed blinds and replace them with the half blinds so late in the project. As a result this innovative energy-saving feature is completely ineffective. In the future the client should consider providing a training or educational seminar for the tenants or building occupants regarding the benefits and use of a buildings energy-saving and sustainable features prior to occupancy. It appears that the tenant in this case did not understand the daylighting feature and chose to override it by installing floor-to-ceiling blinds.

Occupancy Sensors

The occupancy sensor for the building spaces were commissioned and adjusted as needed. However, since the tenant has moved into the space, furniture placement choices have resulted in covering some of the occupancy sensors to the extent that they are no longer affective. This issue needs to be revisited and either the occupancy sensors or the furniture should be relocated to take full advantage of this energy efficiency feature.

O&M Manual Review

The operations and maintenance manuals were reviewed by the commissioning team to ensure that the correct components were included. There were a total of thirty-five (35) comments on these manuals. Some of the items noted during this review were:

- Provide names, addresses and telephone numbers of vendors.
- Mark equipment used on the project.
- Provide test and balance information.
- Provide information on Reclaim Coil, Water Heater, Vibration Isolation, Sprinkler System, Grilles, Diffusers, TVSS, Interior lighting control, Automatic Transfer Switch and As-Built drawings.
- Provide extra / spare lamps
- Provide tools for preventative maintenance.
- Only include data provided on this project.

Appendix F contains the full list of issues identified as part of the O&M manual review dated June 6, 2001.

Training

Training occurred on this project between June 4 and June 11, 2001. The owner / user was trained on twenty-one (21) systems on the project. The commissioning team reviewed training agendas and attended most training sessions to insure that the training went smoothly. All training sessions appeared to be very informative to the users and staff. The users commented that they were very glad that the commissioning agent reviewed and attended training to help spur dialogue regarding the operation of the equipment. Appendix K – *Training* contains a list of equipment that the user received training on, along with issues that came up during this training.

Future Commissioning Recommendations

We have accumulated several recommendations for commissioning on future projects. These are as follows:

1. Commissioning should be clearly addressed in the contract documents. This includes construction and acceptance phases of commissioning. This can be in the form of a separate section for commissioning (ex: Section 17) or by stating requirements under each section with a recap that outlines all parties' involvement in the commissioning process along with the related specification that requires this involvement. We found on this project that the recap was a very valuable tool. The project specifications vaguely addressed construction and acceptance commissioning. The client was very apprehensive about how to include commissioning in the specifications because when the project was first appropriated, it was unclear if funding would be adequate to include commissioning beyond the design phase. Therefore the specification contained language that was somewhat vague regarding how commissioning would be performed during construction. However, it did include enough language to require a fairly typical level of commissioning by the contractor. Problems arose because the word "commissioning" didn't appear in the specification. The contractor believed that commissioning was not clearly stated in the specification to be part of the project, and stated on several occasions that they felt they were due a change order for this service. Subsequently, the construction team was very reluctant to accept the commissioning agent as part of the team and made it difficult at times for the commissioning agent to perform their duties. A great deal of time and documentation was provided by the commissioning agent to help convince the contractor that a certain level of commissioning was included in the project. In our experience, when contractors understand the commissioning process and it is clearly specified, they see how it benefits them and are willing partners in the process. In future projects, the client should consider bidding the commissioning of the MEP systems as an alternate. This will allow an accurate and competitive bid value to be assigned to this task.

2. Include commissioning during project conception. It is quite possible that the problems stated in the first recommendation regarding the lack of a rigorous commissioning specification would not have occurred if commissioning had been included during the initial budget development for the project. The project budget

needs to consider commissioning for all stages of the project from design through acceptance. Although a great deal can be accomplished through design phase commissioning, construction and acceptance phase commissioning is where proof occurs that design intent is actually met. Performance testing ensures that all of the systems work together in an integrated manner. However, before the commissioning provider can execute the performance testing, the contractor must have the systems in readiness through a series of prefunctional tests done during start up. If this can't be clearly specified then communications often break down. Including commissioning during project conception and budgeting facilitates communication and the understanding by all team members that commissioning is important to the Client.

3. Value Engineering should be performed on the project by the commissioning team prior to bidding the project. This way, questionable items can be bid as alternates and competitive bid pricing can be seen for these items in lieu of waiting until a contractor is already on board and negotiating a price with one contractor. The contractor has no incentive to offer a low price for items once the project is awarded to them.

4. It should be made clear with the designers and contractors that the commissioning agent is part of the construction team. This is to make sure that all correspondence and construction related information is passed along to the commissioning agent. Several items did not get conveyed to the commissioning agent in a timely manner. Some of these items included:

   - CO detection system
   - Circuit for sump pump
   - Stacking of VSD
   - Relocation of water heater

   Because the commissioning agent was not copied on most correspondence on this project, it was very difficult to understand what change orders and modifications were approved and should be built. For example, we did not know whether the CO detection system was approved, so when drywall was installed and no rough-ins were made for this system, we assumed that this item was not approved by the owner design team. Once we questioned the designers, it was learned that the system had been approved several weeks prior to the drywall being installed. If we had known this, we could have questioned the contractor regarding rough-ins prior to the installation of drywall and could have saved the contractor time and money.

5. Specify that the O&M manuals be provided within 30 - 60 days of approved submittals. This would allow the commissioning agent to have access to the needed documentation early in the process. This would have been very helpful on this project because it was difficult to obtain the needed information from the contractor to write prefunctional and functional tests in a timely manner.

6. The completion of the commissioning prefunctional and functional testing should be tied to substantial completion of the project. Once substantial completion is granted on a project, the owner loses a great deal of leverage they have with the contractor. On this project, the contractor was much more responsive to commissioning related items until substantial completion was granted. We have been told by contractors that in most cases the money remaining once substantial completion is granted is so small compared to their total contract that they are willing to lose this portion. We feel that

this is one of the main reasons that commissioning took six months to complete on this project.

7. In the future the client should consider providing a training or educational seminar for the tenants or building occupants regarding the benefits and use of a buildings energy-saving and sustainable features prior to occupancy. It appears that the tenant for this facility, because they lacked an understanding the benefits of the daylighting feature and how to interface with it, chose to override it by installing floor-to-ceiling blinds.

Conclusion

As with most projects, Building X was not without problems. There were many challenges that were addressed by the design, construction and commissioning teams. With this in mind, we feel that while not perfect, the facility is functioning more efficiently and has had much fewer problems due to the commissioning effort performed. It is our feeling that many of the items noted during the commissioning process would have been overlooked or ignored by the contractor and design team if these issues had not been brought to the forefront in a timely manner and resolved. The commissioning process helped the owner become more aware of the issues on the project and their potential for problems during the life of the building if they are not addressed. We feel that the client continues to set an example and should be commended for their untiring effort regarding energy conservation and building sustainability, of which commissioning proves to be a vital tool.

END OF REPORT